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Differential Fecundity and Effectiveness of Contraception*

SOME YEARS AGO my good friend, Alan F. Guttmacher, and his associate, Samuel Rubin, collected from their private practice in Baltimore a series of 1,727 pregnancies which occurred after birth control had been discontinued with the purpose of achieving conception. It was my privilege to make a statistical analysis of this material. In our report,[1] published in 1950, we stated "that the chance of conception was greatest immediately after the discontinuance of contraceptive measures . . . After the first month the chance of conception declined steadily and rather rapidly . . . The explanation . . . is . . . that couples differ considerably in their ability to achieve pregnancy. Those who conceive most easily do so during the first few months after birth control has been given up. As time progresses, the relatively fecund couples have eliminated themselves and only the less fecund and sterile remain." It was further pointed out that "a group of couples practicing contraception successfully is not subjected to the selective process by which the more fecund couples are eliminated . . . Such a population, therefore, retains its high fecundity . . ."

Our contribution of 1950 attracted little attention in medical and demographic literature, possibly because the statistical argument had been too concise. The purpose of the present paper is to restate the case and to illustrate the argument by the use of a model or hypothetical population. This model is based on one set of possible assumptions out of an infinite number the results of which could have served equally well.

The distribution of the Baltimore series of planned pregnancies by time required for conception is repeated in the first column of Table 1.

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* A paper read at a members' meeting of the Eugenics Society on October 15th, 1958.

TABLE 1
PLANNED PREGNANCIES*
BY TIME REQUIRED FOR CONCEPTION

Time required for conception (months)	NUMBER OF PREGNANCIES		Per cent distribution (unweighted average)
	Baltimore	Indianapolis	
One	529	356	34·05
2–3	530	235	27·71
4–6	309	140	16·31
7–12	207	90	10·73
13–24	79	60	5·45
Over 24	73	69	5·75
Total	1,727	950	100·00

*Observed data

Next to it appears a comparable series of 950 planned pregnancies, communicated by C. F. Westoff from the records of the Indianapolis Study.[2] These pregnancies were reported by a sample of nearly 2,000 white Protestant couples interviewed in 1941 and early 1942. The period of married life covered by the histories ranged from twelve to fifteen years; the median age at marriage of the wives was about twenty-one years. The percentage distributions of the two series of pregnancies are quite similar and have, therefore, been averaged in the third column. In the combined distribution 34 per cent of all pregnancies occurred during the first month after contraception had been discontinued, 78 per cent during the first six months, and 94 per cent during the first two years.*

A hypothetical population
We are now ready to start with the construction of our model. Table 2 shows the percent distributions of planned pregnancies, by time

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* No attempt has been made to distinguish menstrual periods and calendar months. It is believed that time required for conception tends to be reported in terms of menstrual periods for short durations and in terms of calendar months for longer durations.

TABLE 2

PLANNED PREGNANCIES IN THREE HYPOTHETICAL GROUPS OF COUPLES*
PER CENT DISTRIBUTION BY TIME INTERVALS

Time interval (months)	Group A	Group B	Group C
1	50·00	10·00	1·00
2	25·00	9·00	·99
3	12·50	8·10	·98
4–6	10·94	19·76	2·88
7–12	1·54	24·90	5·51
13–24	·02	20·26	10·07
Over 24	·00	7·98	78·57
Total	100·00	100·00	100·00

* Assumed pregnancy rates per couple-month of exposure: Group A = ·50, Group B = ·10, Group C = ·01

intervals, for three hypothetical groups of couples, identified as Group A, Group B, and Group C, each group homogeneous in regard to fecundity. * Of these, Group A represents the highly fecund with an assumed probability of conception or pregnancy rate of ·50 per couple-month; Group B is moderately fecund with a pregnancy rate of ·10 per couple-month; and Group C is sub-fecund with a pregnancy rate of only ·01 per couple-month.

In the highly fecund Group A one-half of the pregnancies occur during the first month of exposure. Within six months more than 98 per cent of all couples have achieved pregnancy and most of the remaining couples, within the next six months. In the moderately fecund Group B the process of impregnation is far slower. According to the assumption made, 10 per cent of the wives conceive during the first month after contraception has been discontinued. About 62 per cent of the pregnancies fall into the remainder of the first year and 20 per cent into the second year. In 8 per cent more than two years are required for conception. In the sub-fecund Group C only 1 per cent of the wives conceive during the first month and only 11 per cent during the entire first year. Another 10 per cent conceive during the second

* Throughout this paper, the terms "fecund" and "fertile" and their derivatives are employed according to the usage of demographers; the former denoting reproductive capacity; the latter, reproductive performance. In medical terminology, reproductive capacity is called "fertility" and reproductive performance, "parity".

year and almost four-fifths require more than two years.*

Table 3 presents the per cent distribution of planned pregnancies, by time intervals, in a hypothetical population composed of 60 per cent highly fecund couples, 38 per cent moderately fecund couples, and 2 per cent sub-fecund couples. The numbers of pregnancies

TABLE 3

PLANNED PREGNANCIES IN A HYPOTHETICAL POPULATION*
PER CENT. DISTRIBUTION BY TIME INTERVALS

Time interval (months)	Group A	Group B	Group C	Entire population
1	30·00	3·80	·02	33·82
2	15·00	3·42	·02	18·44
3	7·50	3·08	·02	10·60
4–6	6·57	7·52	·06	14·15
7–12	·92	9·45	·11	10·48
13–24	·01	7·70	·20	7·91
Over 24	·00	3·03	1·57	4·60
Total	60·00	38·00	2·00	100·00

* Composition of hypothetical population: Group A = 60%, Group B = 38%, Group C = 2%

produced by each of the three groups of couples appear in the first three columns and the total for the entire population, in the last column. These percentages and the assumed pregnancy rates in Groups A, B, and C were determined by a process of trial and error until the resulting distribution was very similar to the combined distribution of the observed Baltimore and Indianapolis data. About 34 per cent of pregnancies occur in the first month, 77 per cent in the first six months, and 95 per cent in the first two years.

* The distributions shown in Table 2 were derived in the following manner: First, the monthly probability of conception (p) was converted into the probability of non-conception ($q = 1 - p$). By raising q to the appropriate powers, the probability was then computed of pregnancy not having occurred, 2, 3, 6 12, and 24 months after contraception was discontinued; e.g., for Group B:

q	·9000
q^2	·8100
q^3	·7290
q^6	·5314
q^{12}	·2824
q^{24}	·0798

Finally, q was subtracted from 1·0000, q^2 from q, etc., and the differences multiplied by 100, with the terminal ·0798 × 100 representing the percentage of pregnancies occurring after more than 24 months.

We may now proceed to the computation of pregnancy rates in our hypothetical population, again assuming no permanently sterile couples. The first column of Table 4 shows the number

TABLE 4

COUPLE-MONTHS OF EXPOSURE, NUMBER OF PREGNANCIES, AND PREGNANCY RATES IN HYPOTHETICAL POPULATION* BY TIME INTERVALS

Time interval (months)	Couple-months of exposure per 100 couples	Pregnancies per 100 couples	PREGNANCY RATE	
			per couple-month	per 100 couple-years
1	100	33·8	·338	406
2	66	18·4	·278	334
3	48	10·6	·222	266
4–6	94	14·2	·150	180
7–12	108	10·5	·098	117
13–24	97	7·9	·082	98
Over 24	187	4·6	·025	30
Total	700	100·0	·143	171

* Assuming no permanently sterile couples.

of months of exposure* experienced by 100 couples during successive time intervals after contraception has been discontinued. For the first month the number equals 100 by definition. During the second month after discontinuation only sixty-six couple-months appear because thirty-four wives have already conceived in the first month and are not any longer exposed to the risk of pregnancy. For the same reason, only forty-eight couple-months of exposure are experienced by 100 couples during the third month, ninety-four during the second trimester, 108 during the second half year, and only ninety-seven couple-months during the second full year.

The total number of couple-months of exposure corresponding to the 100 pregnancies of the 100 couples in the hypothetical population is 700. The average exposure or number of months required for conception in our model is exactly seven. We shall return to this figure later on.

The distribution of pregnancies by time

* Couple-months of exposure were computed by multiplying the numbers of conceptions per 100 couples during the time interval (Table 3) by the reciprocals for the probability of conception for each component group, e.g., for the interval 4-6 months:

Group A   6·57 × 2   = 13·14
Group B   7·52 × 10   = 75·20
Group C   ·06 × 100   = 6·00
                          94·34

intervals, in the second column, is the one developed in the preceding table. Pregnancy rates per couple-month of exposure appear in the third column and are finally converted into the more conventional rates per 100 couple-years.

During the first month after the stopping of birth control the pregnancy rate of the hypothetical population reaches the extremely high values of ·338 per couple-month or 406 per 100 couple-years. Subsequently, as we had concluded in our study in 1950, "the chance of conception declines steadily and rather rapidly" until a pregnancy rate of 98 per 100 couple-years prevails during the second year and a rate of only thirty thereafter.

In mathematical terms, the pregnancy rate of the hypothetical population during the first month of exposure is the arithmetic mean of the probabilities of conception assumed for the three component groups of couples. The pregnancy rate for the total period of exposure, until all couples have achieved pregnancy, is the harmonic mean of the component probabilities.

It is now necessary to introduce the factor of permanent sterility into the hypothetical population. For purposes of illustration it was assumed that 5 per cent of the couples discontinuing contraception are unable to achieve pregnancy at any time. The effect of this assumption which would seem to be more applicable to women in their late twenties or early thirties than to younger women[3] is illustrated in Table 5.

TABLE 5

COUPLE-MONTHS OF EXPOSURE, NUMBER OF PREGNANCIES, AND PREGNANCY IN HYPOTHETICAL POPULATION* BY TIME INTERVALS

Time interval (months)	Apparent couple-months of exposure per 100 couples	Pregnancies per 100 couples	PREGNANCY RATE	
			per couple-month	per 100 couple-years
1	100	32·1	·321	385
2	68	17·5	·258	310
3	50	10·1	·200	240
4–6	105	13·4	·128	154
7–12	132	10·0	·076	91
13–24	152	7·5	·049	59
1–24	607	90·6	·149	179

* Assuming 5% of couples permanently sterile.

The apparent number of couple-months of exposure per 100 couples in each time interval is larger than in the absence of permanent sterility because fewer couples are eliminated by pregnancy. Permanently sterile couples are, of course, not exposed to pregnancy, but since they cannot be identified, they must be included. The number of pregnancies in each interval is 5 per cent smaller. The pregnancy rates are 5 per cent lower in the first month and this difference increases to 40 per cent during the second year after the discontinuation of birth control. The computation ends at this point as it cannot be carried into an open-ended interval.

Effectiveness of contraception

So far, we have been concerned with planned pregnancies, assuming tacitly that birth control was practiced with complete success prior to its discontinuation. Our next objective is to compute pregnancy rates with use of contraception, assuming various degrees of incomplete protection. The starting point is the hypothetical population previously constructed, with 5 per cent of the couples permanently sterile, and the first assumption as to the effectiveness of control is a reduction of 90 per cent in probability of conception for every couple in the population.

The results of this computation are summarized in Table 6. The apparent number of

TABLE 6
COUPLE-MONTHS OF EXPOSURE, NUMBER OF PREGNANCIES, AND PREGNANCY RATES IN HYPOTHETICAL POPULATION, BY TIME INTERVALS, WITH USE OF CONTRACEPTION*

Time interval (months)	Apparent couple-months of exposure per 100 couples	Pregnancies per 100 couples	PREGNANCY RATE	
			per couple-month	per 100 couple-years
1	100	3·2	·032	38·5
2–6	455	14·0	·031	36·9
7–12	462	13·1	·028	34·0
13–24	729	17·8	·024	29·3
1–24	1,746	48·1	·0275	33·0

* Assuming 90% reduction of pregnancy rates.

couple-months of exposure, shown in the first column, is much larger than in Table 5 without

contraception because far fewer couples are eliminated by pregnancy. The number of pregnancies is reduced by nine-tenths in the first month and by about two-thirds for the period of 2-6 months. From the second half year onward, the number of pregnancies per 100 couples is larger than without contraception, reflecting the larger number of couple-months of exposure. The pregnancy rate in the first month is likewise reduced by nine-tenths, from 385 to 38·5 per 100 couple-years of exposure. As in the previous model, the pregnancy rates decline in successive time intervals, in this instance, to 29·3 per 100 couple-years during the second year. This decline is far less steep than the corresponding decline without contraception from a rate of 385 to one of 59 per 100 couple-years.

Other assumptions as to the effectiveness of contraceptive practice are illustrated in Table 7

TABLE 7
COUPLE-MONTHS OF EXPOSURE, NUMBER OF PREGNANCIES, PREGNANCY RATE, AND PREGNANCY POTENTIAL IN HYPOTHETICAL POPULATION, WITH CONTRACEPTION*

Reduction of pregnancy rate (per cent)	Apparent couple-months of exposure per 100 couples	Pregnancies per 100 couples	Pregnancy rate per 100 couple-years	Pregnancy potential per 100 couple-years
90	1,746	48·1	33·0	330
95	2,022	30·1	17·8	356
98	2,234	13·9	7·5	375
99	2,314	7·3	3·8	380

* Assuming 90%, 95%, 98% and 99% reduction of pregnancy rates and a time interval of 1–24 months.

for a time interval of two years. The additional levels of reduction in probability of conception are 95 per cent, 98 per cent, and 99 per cent The number of couple-months of exposure during two years increases with effectiveness of contraception, approaching a maximum of 2,400 if no pregnancy were to occur. The number of pregnancies per 100 couples during two years ranges from 48·1 at the 90 per cent level of effectiveness to 7·3 pregnancies at the 99 per cent level. Compared with the 90·6

pregnancies during two years in the hypothetical population without contraception, as shown in Table 5, the differences are 47 per cent and 92 per cent, respectively. The percentage reduction in the number of pregnancies over a given period is thus far smaller than the corresponding assumed reduction in probability of conception for each couple. The gamut of pregnancy rates from a high of 33·0 per 100 couple-years of exposure at the 90 per cent level of contraceptive effectiveness to a low of only 3·8 at the 99 per cent level encompasses most of the rates reported in the literature for real populations using various contraceptive methods.

The last column of Table 7 shows the pregnancy potential per 100 couple-years as a measure of the fecundity retained by the hypothetical population at each assumed level of contraceptive effectiveness. The pregnancy potential is ten times the pregnancy rate at the 90 per cent level of effectiveness, twenty times at the 95 per cent level, fifty times at the 98 per cent level and 100 times at the 99 per cent level. The pregnancy potential increases with the effectiveness of contraceptive practice, but the range is comparatively narrow from 330 at the 90 per cent level to 380 at the 99 per cent level and 385 at the theoretical maximum with completely successful contraception. If the couples practising birth control were to abandon it, their uncontrolled pregnancy rate during the first month would equal their pregnancy potential. In subsequent months the rate would decline rapidly, following a pattern similar to that shown in Table 5.

Post-partum sterility

It is now time to abandon the comparatively firm ground of our hypothetical population to carry the exploration forward into new and inadequately known territory. It has long been known that the average interval between two pregnancies, in the absence of contraception, is substantially longer than the average time required for conception after the discontinuation of birth control or between marriage and the first conception without attempts to postpone the latter.* It is possible to estimate the order of magnitude of this delay. In the classic study by Stix and Notestein[4] of 991 women who had attended a birth control clinic in New York City, the average interval between pregnancies was about twelve months, including the allowance of one month for the puerperal period. The average time required for planned conceptions was 3·3 months. The delay of conception following a preceding pregnancy was, therefore, on the order of nine months. Among the 1,444 "relatively fecund" couples of the Indianapolis Study the average time between pregnancies was about thirteen months; the average time required for planned conception, 4·2 months; and the delay following a preceding pregnancy, again nine months. Similar estimates of the delay of conception after a pregnancy can also be derived from data on intervals between successive live births, as compared with the time between marriage and first birth, in highly fertile populations that did not or do not practice family limitation, such as the French Canadians[5] of the eighteenth century and the Hutterites[6] of the Western plains in our own times.

By adding nine couple-months of post-partum inability to conceive to the seven months computed from Table 4, one arrives at an average uncontrolled interval between pregnancies of sixteen months. If one month is deducted for the puerperium, as is customary among American authors in this field, the corresponding pregnancy rate for the hypothetical population without any use of contraception is 80 per 100 apparent couple-years of exposure (1,200 ÷ 15 = 80). This rate, based on the experience of couples of continuing fertility (excluding exposure prior to the first pregnancy), corresponds to the rate of 171 shown in Table 4 based on planned pregnancies after discontinuation of contraception.

A normal period of post-partum sterility

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* Time required for conception tends to average longer for first marital pregnancies not preceded by contraception than for planned pregnancies. The difference is, however, small (1-2 months) in relatively homogeneous populations such as those cited here. One reason for the longer average time required for the first marital pregnancy is premarital conception, since among those with premarital coitus the more fecund couples are more likely to achieve pregnancy prior to marriage than the less fecund couples.

averaging nine months is not fully explained by the information now available on the physiological factors that are involved. Guttmacher,[7] who reviewed this subject a few years ago, estimated the average duration of post-partum amenorrhea in the absence of lactation at about two months, followed by two anovulatory cycles to a total of four months. If the child is suckled, the corresponding period may well be nine months or even more, but prolonged breast feeding has not been the common practice among the urban populations in the United States from which our rough estimate of the duration of post-partum sterility has been derived. While the uncertainty as to average duration of post-partum sterility does not affect the argument which follows, it is to be hoped that further research in this area will have high priority.

Clinical implications

The extended average period of post-partum sterility has important implications for the computation and evaluation of pregnancy rates with use of contraception. A group of couples, studied as users of a particular method of birth control, may include any or all of the following components: (1) couples starting to use the method at marriage or after a period of separation during which coitus did not occur; (2) couples starting after a preceding pregnancy just before the first post-partum ovulation; (3) couples starting one or several months before the first ovulation; (4) couples starting one or several months after the first ovulation; and (5) couples switching from another method of contraception to the one which is being studied.

Couples in categories 1 and 2 find themselves exactly in the situation illustrated in Tables 6 and 7. At the onset of contraceptive practice, their fecundity is at the maximum, represented in our model by a pregnancy potential of 385 per 100 couple-years. In subsequent months the fecundity is slowly dissipated. Category 5 may be assimilated to 1 and 2 since the loss of fecundity is quite slow even at a comparatively low level of contraceptive effectiveness.

The situation is different in regard to category 3, comprising those starting contraceptive practice some time prior to the first post-partum ovulation. For these couples, the pregnancy potential is zero during the early part of their contraceptive practice. The average pregnancy potential for the entire period of use may be substantially reduced, especially if contraception is initiated soon after delivery and if the follow-up period is short.

Category 4, on the other hand, comprises couples starting birth control some time after the first post-partum ovulation and has, therefore, been subject to the rapid process of attrition illustrated in Table 5. Many of the more highly fecund couples achieve pregnancy early and by the time contraception has begun, a large proportion of the remaining couples is only moderately fecund or sub-fecund. While later losses of pregnancy potential, during contraceptive exposure, are slow, the average potential may be substantially below the maximum represented by categories 1, 2 and 5.

Previous studies of the effectiveness of contraceptive methods have, as a rule, paid little attention to the interval since a preceding pregnancy and to the use of other contraception during that period. Months of post-partum amenorrhea have generally been included in the computation of pregnancy rates. It would appear, therefore, that most of the published rates are below the levels that would have been obtained if all couples had started birth control at the time of maximum fecundity.

To ensure a high degree of comparability it would be most desirable that studies of the effectiveness of contraception should be based on groups entering observation at the point of maximum fecundity. This is not practicable since the proportions of couples in categories 2, 3 and 4 cannot be readily determined owing to the fact that the reappearance of menstruation may precede the first post-partum ovulation by a number of months. To be sure, the occurrence of ovulation can be determined by various tests, such as endometrial biopsy or temperature charting. However, these procedures can hardly be incorporated into the design of contraceptive research, especially since repeated tests over several months would be required.

As a substitute for an impracticable determination of the first post-partum ovulation, the National Committee on Maternal Health

has recommended in a recent publication[8] statistical procedures designed to minimize the reduction of fecundity resulting from the early or late starting of contraceptive practice. Setting up criteria for the inclusion of couples in studies of the effectiveness of contraceptive methods, the Committee recommends that "at the time of prescription, the interval since the most recent pregnancy should not exceed six months without contraception or five years with contraception" and further that periods of "post-partum amenorrhea should . . . be omitted" from the computation of pregnancy rates. Application of these rules would result in an approximation of the maximum pregnancy potential, especially if the average period of use of contraception is sufficiently long. The Committee recommends that it should be at least one year.

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